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WASTEWATER FROM SMALL COMMUNITIES AND IMPACTS TO ESTUARINE WATER QUALITY USED FOR AQUACULTURE

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THE UNIVERSITY OF NEWCASTLE AUSTRALIA

Estuaries & Aquaculture

- Estuaries receive runoff containing nutrients and pathogens from various land-uses eg agriculture, effluent from wastewater systems
- Oysters are critical indicators of estuary health as they filter feed & concentrate microorganisms – referred to as the "canary of the estuary"
- Aquaculture in many places worldwide is under threat from declining water quality in river systems & estuaries

Oyster industry 'will die in 20 years'

SMH 28/10/02

Stephanie Peatling
Environment Reporter

The alarm is being raised over the condition of the state's rivers after a report found the oyster industry could be wiped out within 20 years because of a drop in water quality.

The NSW Healthy Rivers Com-

PEARL JAM

- The NSW oyster industry employs about 1200 people.
- In 1999/2000 the value of oyster production was $30 million.
- The majority of oysters eaten in Australian restaurants are Sydney rock oysters.

Estuary Monitoring – Oyster Quality – Two Guidelines

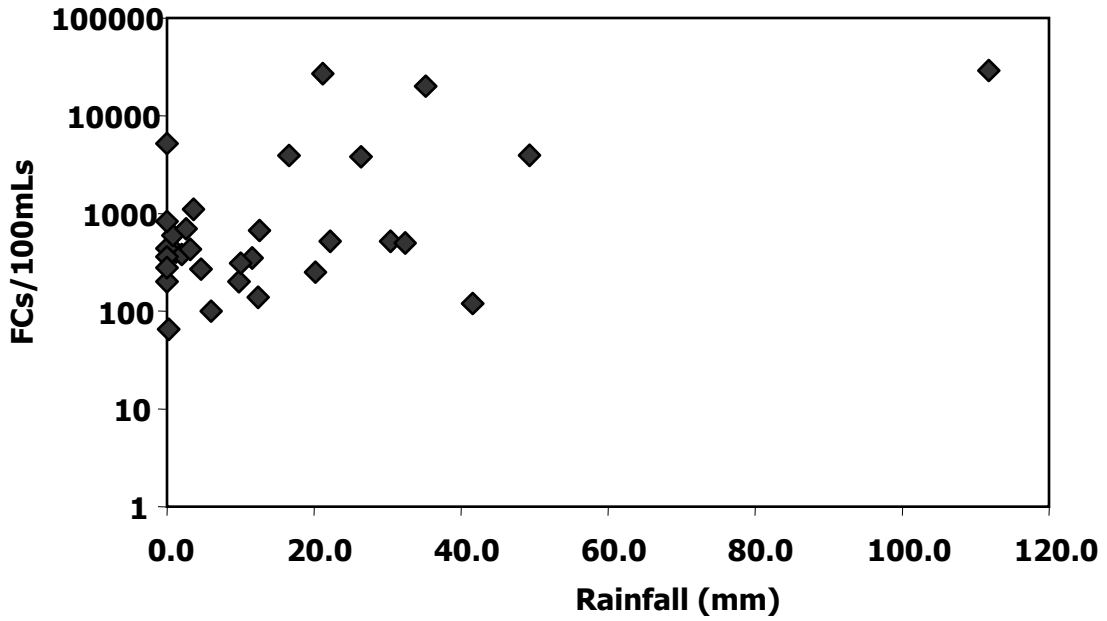
- NSW Shellfish Quality Assurance Program (SQAP) implemented to ensure that shellfish meet relevant public health standards - oysters collected (by industry) for analysis (faecal coliforms & E.coli) when > of 25 mm rainfall is recorded within 24-hours and when the salinity of the estuary is less than 18 ppt

- Aust Environmental guidelines - water for shellfish culture should have median FC < 14/100 mL (not > 10% samples >43/100 mL)

- SQAP guideline for waters <88/100 mL, tissue < 5 E.coli/g

Catchment Monitoring

- Relationship between faecal coliform counts (cfu/100mL) in estuarine waters & catchment rainfall (Tilligerry Creek data, Port Stephens NSW)



Examples – Wallis Lake (1997)

- Faecal contamination of shellfish in Wallis Lake, North Coast NSW – major viral outbreak (*Hepatitis A*) in January 1997 (442 cases throughout Australia - 274 in New South Wales - one fatality)
- Sanitary survey identified a number of potential sources of faecal contamination - individual source(s) not able to be clearly identified

- Human waste suspected as major contributor to faecal contamination in estuary, although source not confirmed in subsequent studies

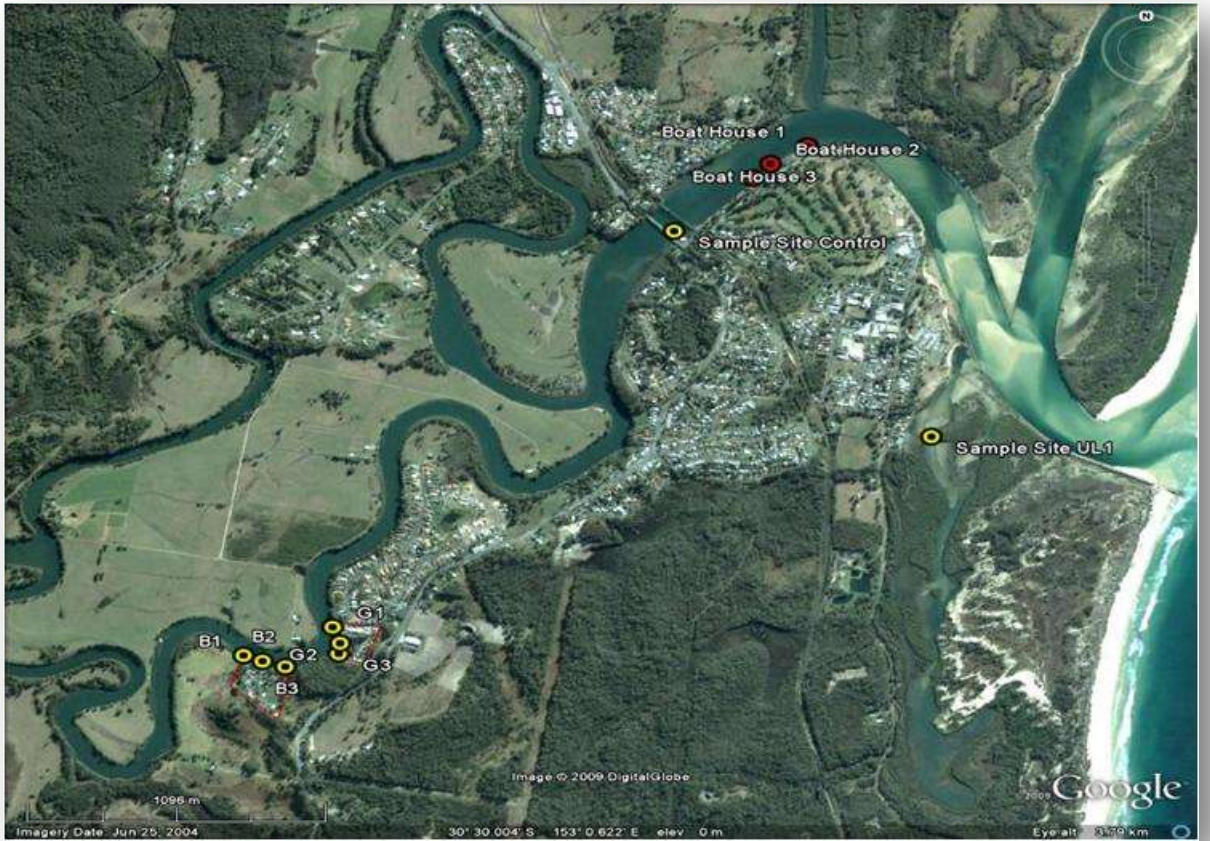
Examples - Port Stephens (2005)

- Reports over last 10 years describing faecal contamination of Tilligerry estuary - mixed land use watershed in Port Stephens in New South Wales

- Shellfish monitoring in 2005 by Safefoods NSW indicated presence of human viruses (norovirus; adenovirus) in oyster tissue resulting in closure of part of estuary for harvesting for 2 years

Kalang River, NSW: Oyster associated gastroenteritis outbreaks 2008

- Two gastroenteritis outbreaks in July 2008 linked to oyster consumption – potential source human waste - analysis indicated norovirus – in 2011 estuary remains closed to commercial harvesting



Background

- 12% population serviced by on-site systems
- Are small on-site wastewater systems sustainable?
- Do large numbers of individual system failures lead to cumulative impacts if we use contamination of water quality in estuaries as primary criteria?
- Is declining surface & groundwater quality related to the contribution they make?
- Are there any risks associated with public health from these systems or from small STP discharges?

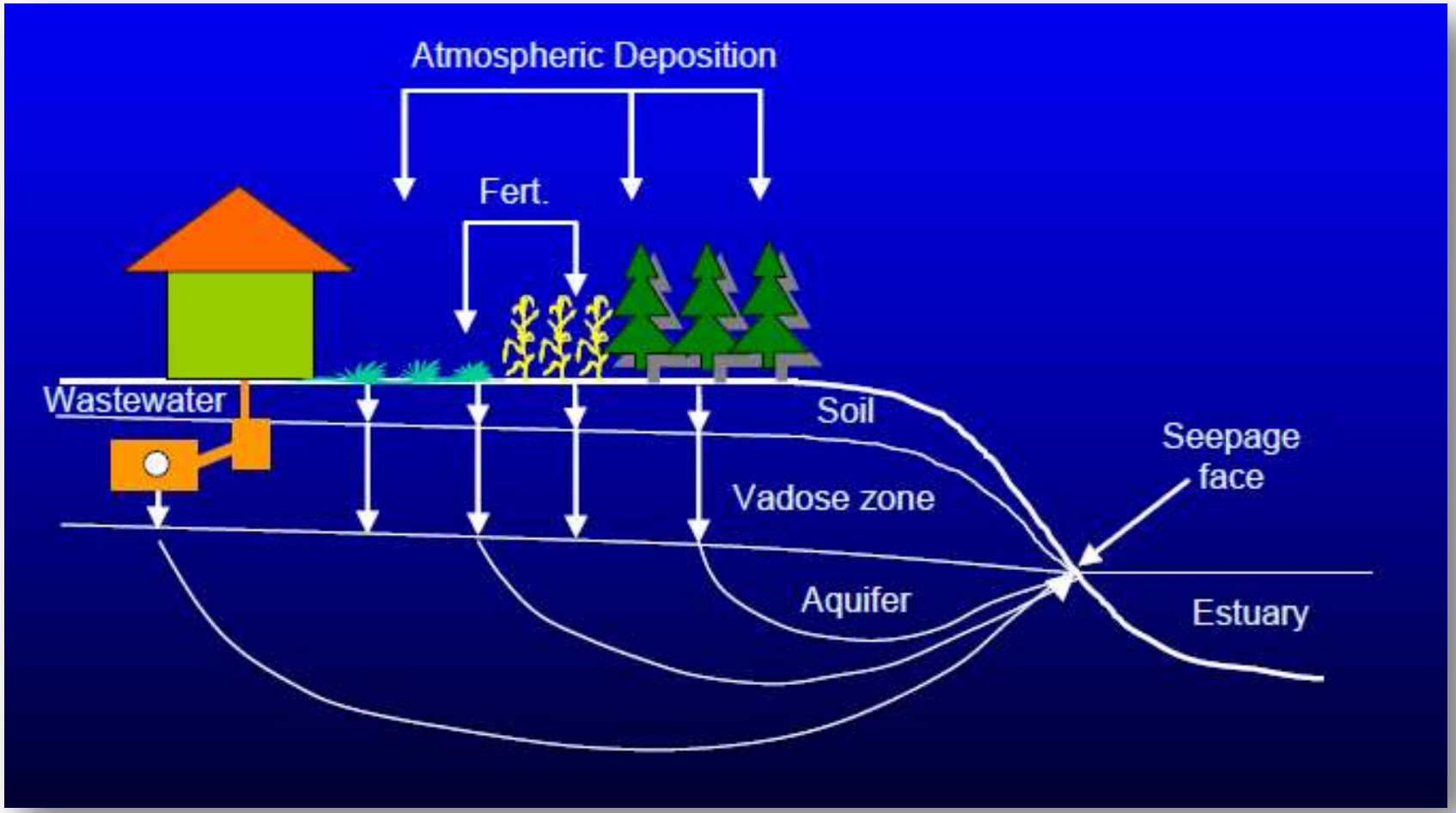
On-site Wastewater System Performance in Australia

- Research over the last 20 years suggests that many on-site wastewater systems perform poorly and may fail

	Location	Number	% failing
Geary (1992)	Adelaide Hills (SA)	118	23
O'Neill et al (1993)	NSW	200	47
Jelliffe (1994)	Maroochy (Qld)	101	27
Kinhill (1997)	Caboolture (Qld)	77	45
Arnold & Galasch (2001)	Mt Lofty Ranges (SA)	1400	40
Potter et al (2004)	Caloundra (Qld)	550	25
Whitehead et al (2010)	Loch Sport (Vic)	150	High using variable criteria

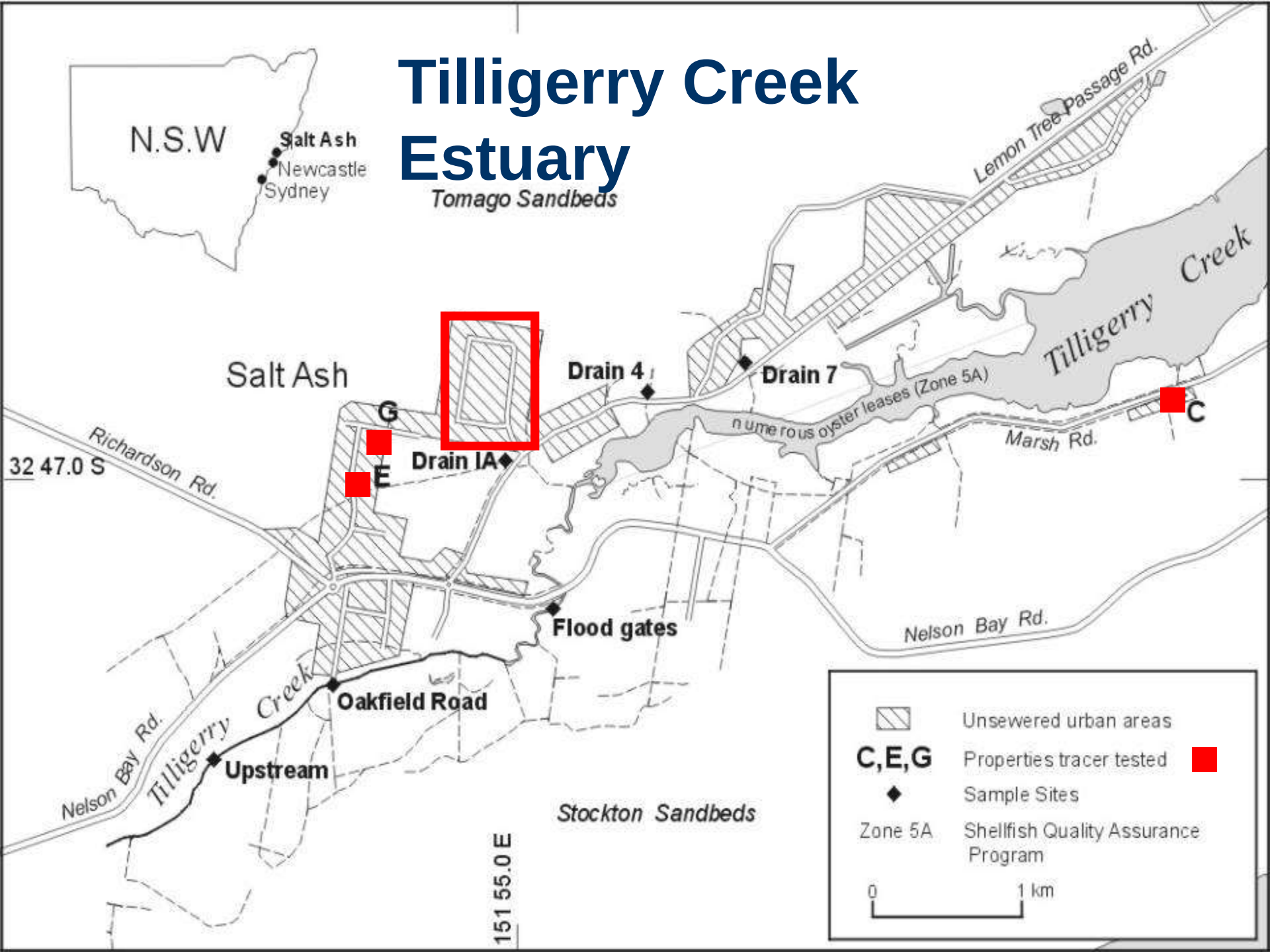
- Despite this high incidence of failures… "evidence for off-site environmental & public health impacts ranges from sparse to ambiguous" (Gardner *et al*, 2005)

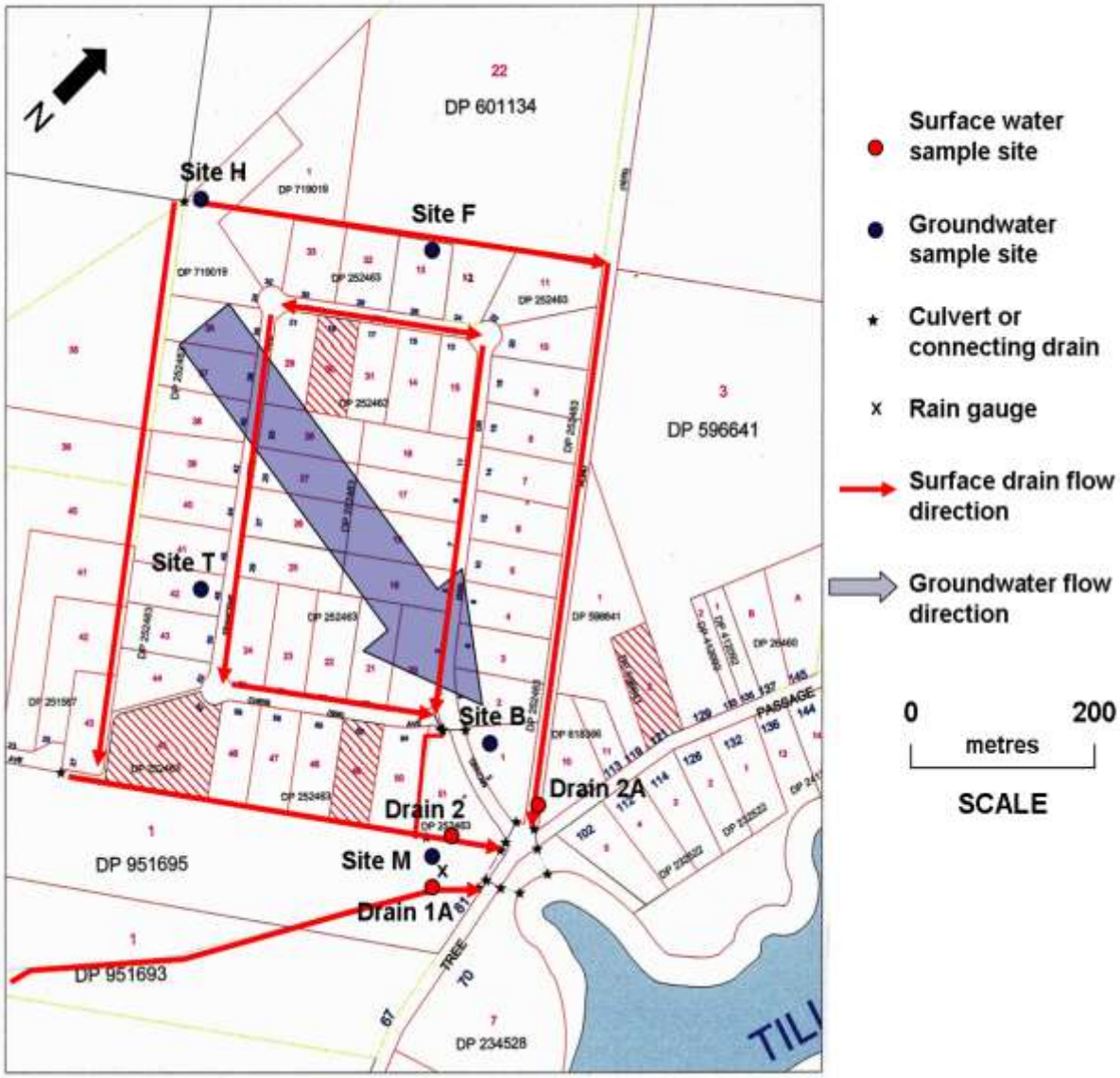
On-site Wastewater System Pathways to Estuaries



Tilligerry Creek Catchment

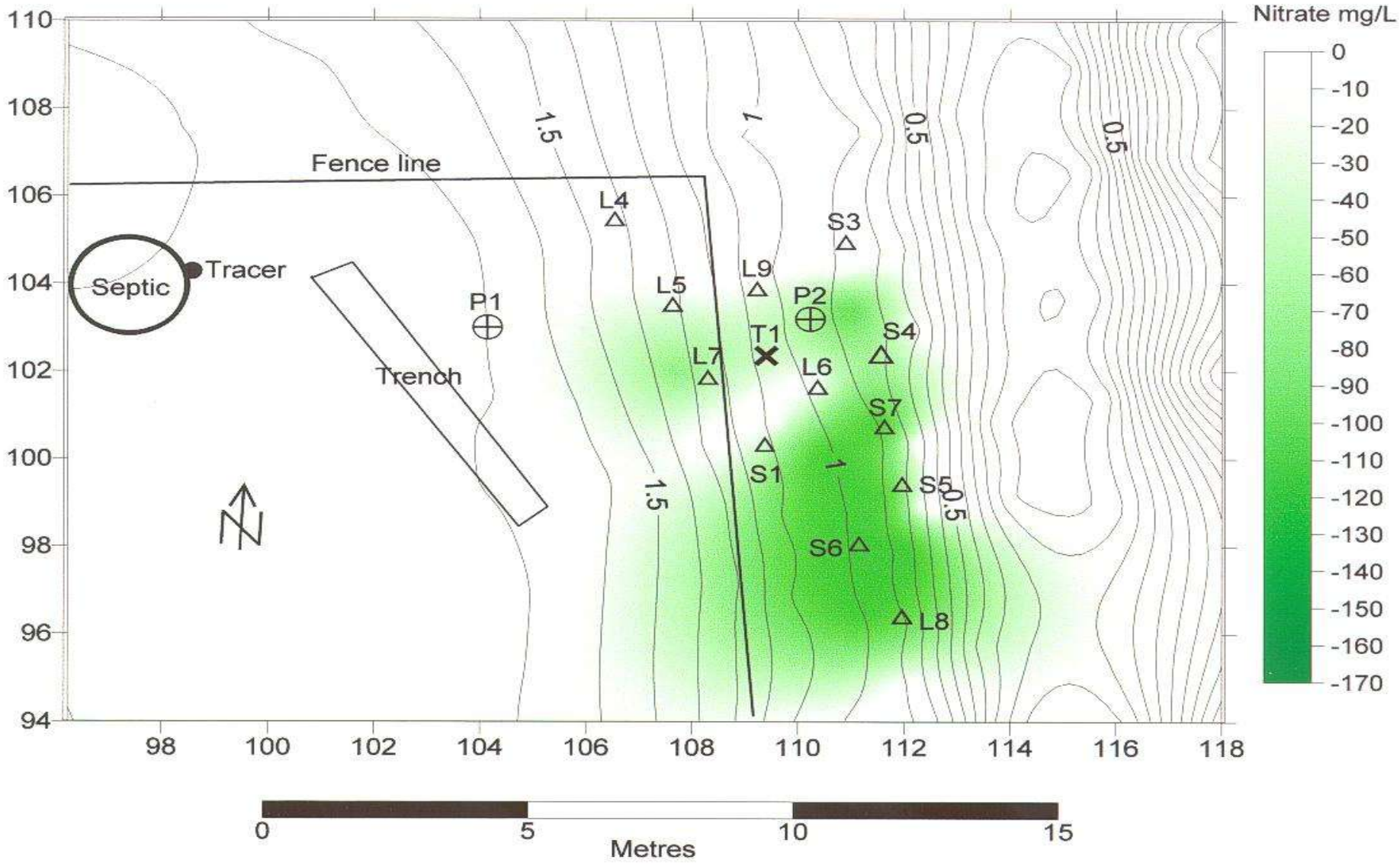
- 30 kms north of Newcastle, NSW – estuary producing 7% of State's commercial oysters valued at $2.4 M/a (previously 25%)
- Coastal sands, characterised by shallow groundwater table (0 - 3 m), network of drains to take drainage waters to estuary - various mixed agricultural land use activities
- Over 300 on-site systems near estuary in community of Salt Ash, some in estuarine muds, most in coarse freely draining sands
- Audit results at Salt Ash indicated high rates of on-site system failure > 66% with some problems; 11% in "high risk" locations (septic system density 70/km^2)


Tilligerry Creek Estuary
N.S.W
Salt Ash
Newcastle
Sydney
Tomago Sandbeds
Lemon Tree Passage Rd.
Tilligerry Creek
Salt Ash
Drain 4
Drain 7
G
E
Drain IA
numerous oyster leases (Zone 5A)
C
Marsh Rd.
32 47.0 S
Richardson Rd.
Flood gates
Nelson Bay Rd.
Oakfield Road
Tilligerry Creek
Nelson Bay Rd.
Upstream
Stockton Sandbeds
151 55.0 E
Unsewered urban areas
C,E,G
Properties tracer tested
Sample Sites
Zone 5A
Shellfish Quality Assurance Program
0
1 km



Monitoring and Field Work

Nitrate Plume

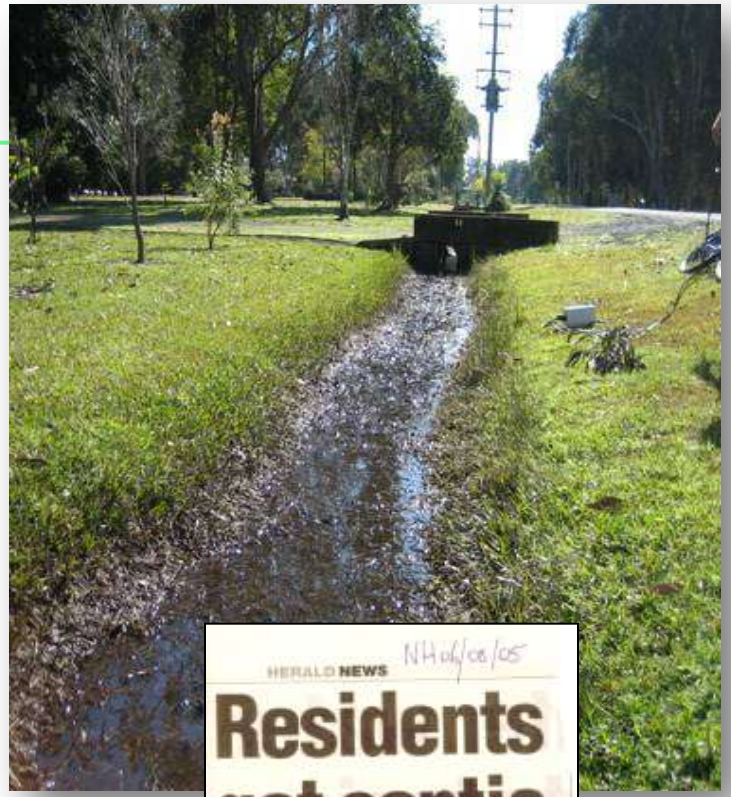


Microorganism Transport to Surface Drains

- Monitoring showed faecal bacteria present in drains – approx. 3-log reduction in FCs during transport from ST to drain (typically 10^2 cfu/100 mL)
- *Are the microorganisms in drains actually human & could they survive transport to estuary?*
- Calculated viral transport using 5×10^3 human enteric viruses/L & inactivation rate at 13^{o}C of 0.223/day for MS-2 bacteriophage (viral surrogate) shows human viruses could be present in drains
- Need to be able to identify human sourced contamination!

On-site Wastewater Systems Implicated

- High groundwater table, sandy soils & issue of contaminant transport to estuary
- Major management implications associated with clean up of approved systems
- Loss of productive aquaculture area from estuary closure; damage to industry and loss of jobs & income



HERALD NEWS

Residents get septic tank order

Farmers up the creek

Contaminated oyster zone locked away

By PETER AUSTIN

Land The
Thursday 28/9/2006

Estuary Remediation

- Re-inspection of on-site systems
- Preparation of Catchment Management Plan
- Investigation of sewerage options; centralised, decentralised; improved on-site
- Upgrades identified & in some cases construction of Wisconsin Sand Mounds
- Standard designs commissioned & included in Council on-site specs.
- A total of 67 mounds within area with more being constructed – most in coastal estuarine areas

Research to Trace Contaminant Sources in Estuaries

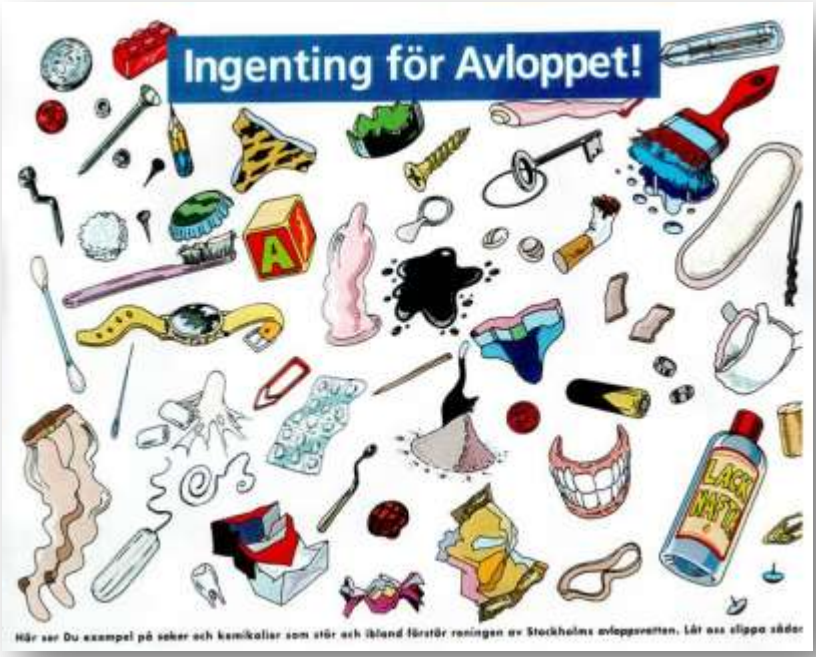
- Sources of faecal contamination in shellfish could be human or animal
- Two approaches adopted which involved effluent tracing techniques;

  (I) use of chemical & fluorescing tracers to mark pathways of solute movement for travel time & dispersion of pollutants

  (II) microbiological tracing using bacterial source tracers

Chemical Tracers in Effluent

- By-products of human metabolism end up in domestic wastewater
- Physico/chemical indicators not definitive eg. electrical conductivity; chloride; nitrate; ammonia
- Sources of domestic effluent in the natural environment – STPs/on-site wastewater systems

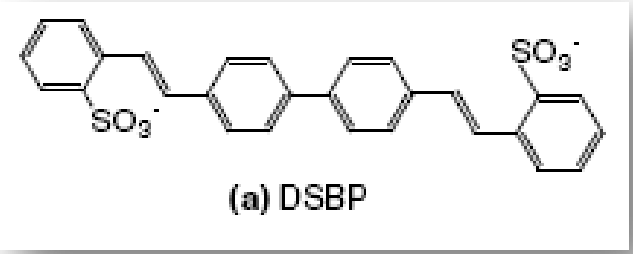


What goes in the top end affects the bottom end

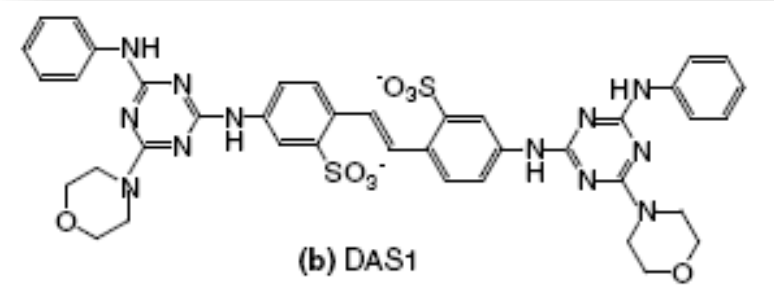
Tracer Examples in Effluent

Some indicators uniquely indicate domestic effluent as a contaminant source (compared to other catchment sources)

- fluorescing optical brighteners (whitening agents) (FWA) in household washing products - added to washing powders to adsorb to fabrics and brighten clothing by fluorescing when exposed to ultraviolet light. Research suggests they may be good indicators of human contamination in environmental waters – Fluorimeter or HPLC determination



(a) DSBP



(b) DAS1

FWCs available comprises distyrylbiphenyl (DSBP) – Figure a and diaminestilbene (DAS) – Figure b types.

Tracer Examples in Effluent

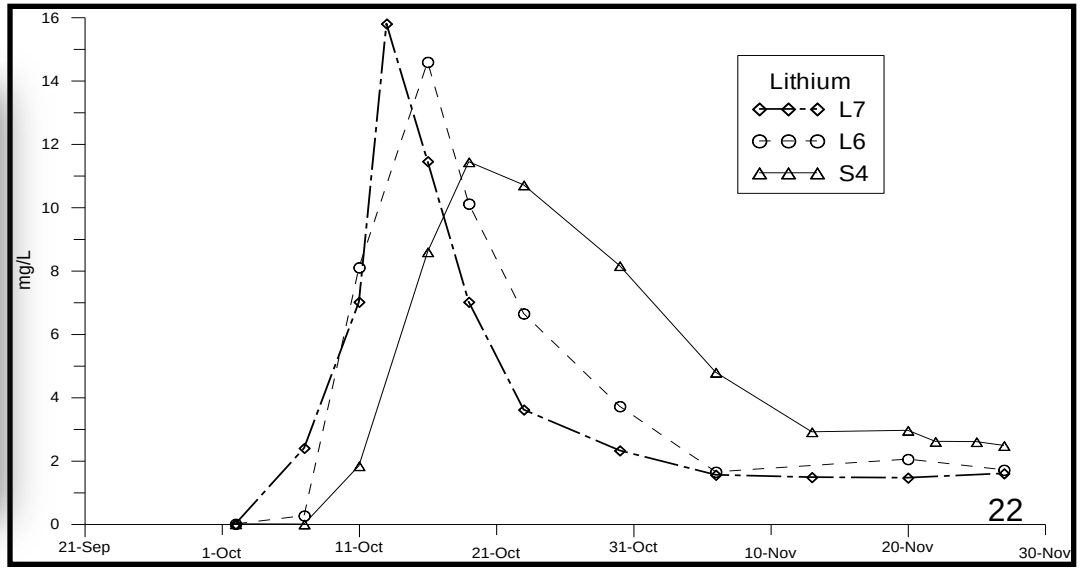
- detergent chemicals eg.sodium tripolyphosphate (STP) used in washing powders & toilet blue

sodium dodecylbenzene sulphonate

- molecular markers eg. human pharmaceuticals, endocrine disrupting compounds, caffeine

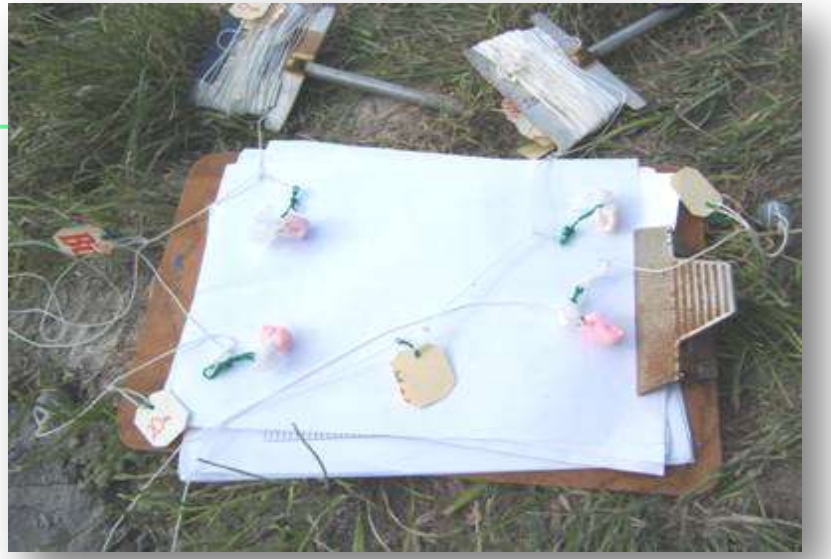
Added Chemical Tracers

- Conservative inorganic chemicals added to determine transport & fate of effluent in surface waters & in tracing contaminant plumes in groundwaters
- Potassium bromide
- Lithium chloride
- Used successfully to identify sources of contamination



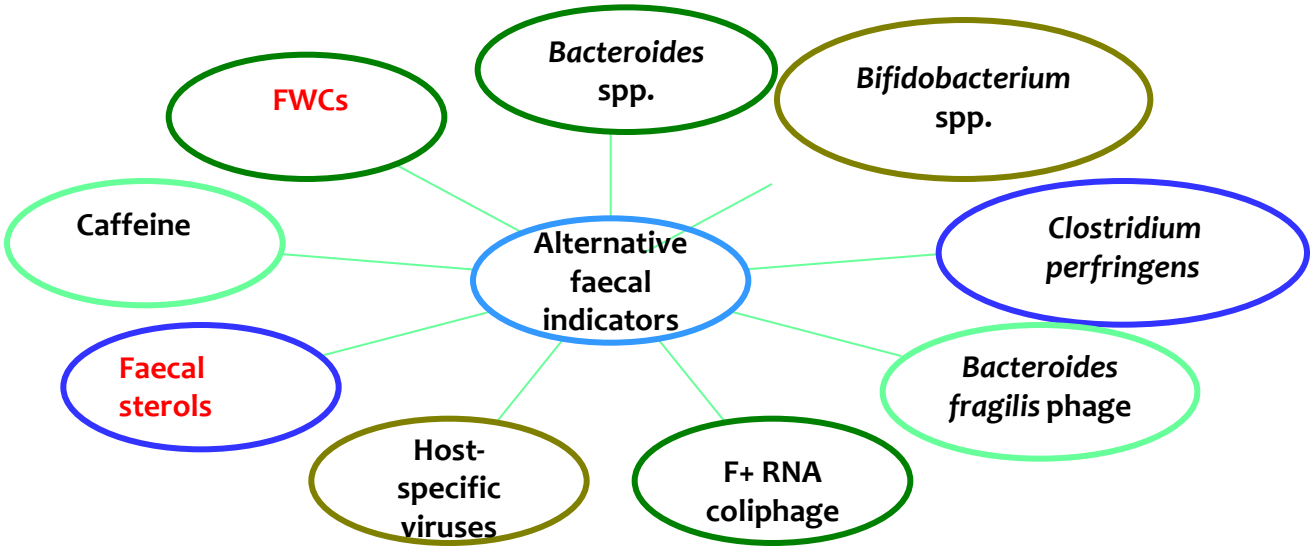
Added Dyes & Fluorescing Tracers

- Organic fluorescent dyes eg sodium fluorescein, pyranine, eosin, rhodamine B and WT) &/or activated carbon packets, resin bags
- Visual inspection, UV light or spectrophotometer for determination



Commonly Used Alternative Indicators of Faecal Pollution

Traditional faecal indicator bacteria used in most monitoring programs, however cannot be used to determine sources eg to distinguish between human & animal



(Ahmed et al 2008)

Bacterial Source Tracking

- Wide variety of microorganisms are water transmissible pathogens- coliform bacteria commonly used indicators & subset Faecal coliforms (FCs)

- Other indicators used include *E. coli*, Faecal streptococci, FC/FS ratios (not useful), species specific indicators eg.*Clostridium perfringens, Streptococcus bovis*

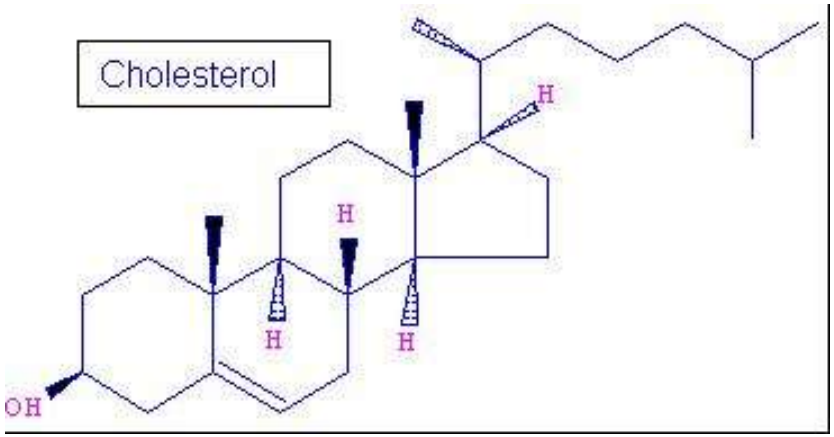
- Range of developing for human biomarker techniques including:

  i) molecular methods eg DNA fingerprinting,

  ii) faecal sterols in fatty acids eg cholesterol breakdown,
  iii) bacterial based approaches eg multiple antibiotic resistance patterns in FC or FS

Biochemical Indicators – Faecal Sterols

- developing method for differentiating between human & animal sources of faecal contamination in waters & sediments



- faecal biomarkers eg bacterial conversion of sterol compounds in fatty acids in digestive tract of mammals - cholesterol breakdown to coprostanol in humans; signif > than in other animals such as dogs/birds

Faecal Sterol Analysis (FSA)

Biohydrogenation by Gut Bacteria

Cholesterol

Coprostanol – Abundant in Human Feces

24-Ethylcoprostanol – Abundant in Herbivore Feces

Cholesterol – Abundant in Dogs & Birds Feces

Distinctive Faecal Sterol Profiles in Different Warm-blooded Animals

Conclusions

- In coastal locations on-site systems may contribute pathogens to estuarine waters used for aquaculture
- Other sources of faecal material such as animal waste also contribute to decline in water quality particularly during wet weather periods
- Results show the presence of human pathogens in estuaries (presumably from small systems) & human enteric viruses could therefore be present
- Process of shellfish contamination is very complex, although clearly some potential risk to human health
- Appropriate treatment & disposal of human effluent required in sensitive coastal environments – management options should involve improving small system performance